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THE WATER SUPPLY & SEWERAGE

OF

COUNTRY MANSIONS AND ESTATES

THE

WATER SUPPLY AND SEWERAGE

OF

COUNTRY MANSIONS & ESTATES

A COURSE OF LECTURES

DELIVERED TO THE

STUDENTS OF THE ROYAL AGRICULTURAL COLLEGE, CIRENCESTER,

AND THE SOUTH-EASTERN AGRICULTURAL COLLEGE, WYE

BY

E. BAILEY-DENTON

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PREFACE.

THE following pages constitute a course of Lectures recently delivered to the Students of the Royal Agricultural College, Cirencester, and of the South Eastern Agricultural College, Wye, Kent. They are not so much intended for the use of those advanced in Sanitary Science or the details of Civil Engineering, as for those of the general public who are interested in the management of estates and country mansions, where the benefits of efficient water supply and sanitation should be specially appreciated.

It has been the Author's desire to trace in detail the history of water from the time when it falls from the clouds in the shape of rain or snow on to the surface of the earth, where it passes through several phases, until, after evaporation by

the sun's rays or other agencies, it again returns to the heavens; and to show how, when water has reached and sunk into the ground it may be conserved and utilised to the best advantage of the community.

E. BAILEY-DENTON.

PALACE CHAMBERS, WESTMINSTER:
June 1901.

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THE

WATER SUPPLY AND SEWERAGE

OF

COUNTRY MANSIONS & ESTATES.

WATER SUPPLY.

WATER in its pure and normal state consists only of two elements—hydrogen and oxygen—in the proportion of two volumes of the former gas to one of the latter, or by weight 11·11 per cent. of hydrogen to 88·88 per cent. of oxygen. In water the two gases of which its substance is composed are chemically combined; but unlike the constituents of the air, they lose their gaseous form and their distinctive properties (both physical and chemical), and thus become a new substance.

Water is no sooner in existence than it loses its normal condition by the absorption of foreign matters with which it comes in contact, and which detract from its purity. This depreciation takes place in its first condition as the vapour of the atmosphere—then as that vapour changes into rain and falls to the ground—then as the collected rain passes over the surface of the earth on its way to

the rivers or, if absorbed, as it percolates through the soil to the subterranean water levels beneath—then as it passes through the earth to find outlet at the surface in the beds of rivers and streams, or in the shape of springs—and lastly, as it is discharged into the sea after it has assumed the form of a river.

The quantity of water placed at the disposal of man depends *firstly* upon the amount of rainfall; *secondly* upon the quantity thrown off impervious surfaces, which, after satisfying vegetation is available for storage above ground; and *thirdly* upon the quantity absorbed by porous surfaces, also, after satisfying vegetation and evaporation, by which nature's underground storage is maintained.

The rainfall in different countries and places varies very considerably in quantity, in season, and in the circumstances which influence its collection, conservation and use. I purpose, however, to limit my observations to the annual amount of rain falling upon the surface of England and Wales. It averages about thirty inches. In the high grounds of the West and North, the average annual depth ranges from 25 inches to 75 inches; whilst in the flat lands on the East and South it varies from 17 inches to 35 inches.

The total quantity of rain which falls on an average of years over the whole of England and Wales amounts to about 27,019,632,000,000 (twenty-seven billion nineteen thousand six hundred and thirty-two million) gallons, which figures, when the

population and its consumption of water is taken into account, prove that each acre of surface, even taking into consideration the East of England, where the average rainfall does not exceed half that of the West, receives as rain nearly eighty times as much water as an average member of the population requires. Of course these figures do not afford any really tangible data for practice, as each requirement must stand upon its own merits, but they give evidence of the ample scope which is at the engineer's command for providing a supply of water for all purposes.

The wettest months of the year are July, September, October and November. With the exception of July, these months occur when summer is on the close, when vegetation no longer requires the same support of moisture as previously, and when evaporation naturally becomes less active with increased moisture and reduced temperature. It is then that, in the case of impervious surfaces, the larger proportion of the rainfall is rendered available for use by storage above ground; or in the case of pervious surfaces, serves to replenish the subterranean supply which nature stores under our feet in the water-bearing strata of the earth.

With pervious surfaces, the proportion of the rainfall absorbed and penetrating the surface of this country in order to maintain our river system varies considerably. On an average of years we find that from one-fourth to one-third of the rainfall, according to the nature of the soil and the

state of husbandry, descends to the subterranean levels. The difference between the amount of rainfall and the above percolation represents the quantity of rain lost each year by evaporation and vegetation. For practical purposes we may assume that it amounts to between 17 inches and 22 inches.

With regard to impervious surfaces, the amount of rainfall evaporated or lost is more difficult to ascertain, but it may be said to fluctuate between 15 inches and 17 inches. The quantity of water thrown off the surface and discharged into our rivers, and by our rivers into the sea, varies in a similar manner; but in the West and North of England, including Wales, it may be taken to be 20 inches, and in the Midland, Southern and Eastern districts it may be taken at 6 inches; all this amount of water is available for storage and the use of man.

The average quantity of water consumed by mankind for drinking and cooking, etc., does not exceed eight gallons per head per day, and in rural districts such as are now under consideration, not more than five gallons a head. Eight gallons, therefore, may be taken as the extreme quantity of water which directly affects the public health, and which, therefore, should be of the purest quality.

The additional supply required for household purposes, such as baths, water-closets, the washing of floors, stable consumption, the washing of carriages, and all other outside purposes, increase the eight gallons to about fifteen gallons. All beyond this quantity is mere waste. Of course it

must be understood that this fifteen gallons per head is exclusive of water used for trade, street watering or for other public purposes. These questions affect towns, not country residences, and will be found to raise the amount given by ten gallons, thus making a total consumption of twenty-five gallons per head in urban districts. There are also special trades in this country which require a far larger consumption of water than even this amount, but they are few and far between, and therefore it is not necessary to again refer to them.

The Rivers Pollution Commissioners appointed by the late Queen in 1868, whose Sixth Report forms the national standard, so to speak, of the quality of water, thus classify the several descriptions at our command.

(*a*) *Wholesome Waters.*—These consist of spring, deep well and upland surface waters.

(*b*) *Suspicious Waters.*—These consist of stored rain water, and surface water from cultivated lands.

(*c*) *Dangerous Waters.*—These consist of river water into which sewage gains access, and shallow well water.

With regard to dangerous waters I need say nothing. As to suspicious waters there is no doubt but that, with the aid of judicious selection and in the case of rain water by artificial filtration, they may often be made almost to rank with wholesome waters; whilst as to wholesome waters it is obvious that their conservation and utilisation are worthy

of the greatest efforts of those who study water economy.

The principal water-bearing strata of England may here be briefly given—

1. The Sands and Gravel which overlie so many of our valleys.
2. The Chalk.
3. The Upper Greensand.
4. The Lower Greensand.
5. The Middle Oolite.
6. The Lower Oolite.
7. The New Red Sandstone.
8. The Millstone Grit.
9. The Carboniferous Limestone.
10. The Old Red Sandstone.

All the above formations throw out springs.

Having now stated the average quantity of rain which annually falls upon the surface of England; the quantity of water which is needlessly wasted when floods occur; and the quantity which descends to the subterranean water levels; and having enumerated the principal water-bearing strata, I will now briefly show how the water at command may be utilised for mansions and estates, including any isolated houses or villages which may be within their limits.

I must here observe, that no matter what source of water supply is determined upon, it is necessary before any expense is incurred in obtaining it, that a chemical analysis should be made; more often than

not this is not done at all, or the sample of water is taken in a careless manner. The result therefore in the latter cases—no matter how good the analyst—is not trustworthy. The correct way to take samples for analysis is to obtain a Winchester quart glass bottle with glass stopper, and to ensure, before it is handed over by the chemist, that it has been thoroughly cleaned with distilled water. Having obtained the bottle and conveyed it to the source of the proposed supply, it is necessary to rinse it out at least three times with the water which is to be analysed before taking the sample. Having taken the sample, the stopper of the bottle should be carefully sealed down in the presence of the taker. The source of supply, or stratum from which the sample is taken, need not be mentioned to the analyst.

Water Supplies by Gravitation.

In many districts of England, especially the hilly portions of the North and West, it is often possible to provide a water supply by means of gravitation; that is to say, a spring may be tapped, or an upland stream may be dammed, at such an altitude as will supply the estate without having recourse to pumping. Under such a fortunate condition of things the first step to be taken after a satisfactory analysis is in either instance to gauge the quantity of water obtainable.

The gauging of a spring or small brook can be

readily carried out in the following manner. An artificial pond should be formed in some suitable position, the bottom and sides of which must be carefully clayed or puddled round, so that no water may escape. Across the lower side of this pond a wooden notch-board, with a sunk weir cut in its centre, should be stretched. This notch-board, with its weir, may be of any suitable dimensions, provided that it is carefully erected, and that the lip of the weir is perfectly horizontal. Of course it is necessary that both the upper and lower sides of the board should be carefully clayed round in like manner as the pond. Within the impounded water a square peg should be driven, the top of which should be at precisely the same level as the weir, and from this peg, when the pond has filled up to and above the level of the weir, the depth of water in inches flowing over it can be accurately ascertained, and thus its quantity determined by means of published tables, such as those of Beardmore and Box. These gaugings should be taken frequently for at least a month, preferably speaking during the dry months of the year.

With a brook—the width and depth of which are too great to introduce the notch-board and weir—the best method of gauging its discharge is to stake out a certain distance—say 100 or 200 feet—along the straightest avaliable portion. Several cross-sections should then be taken at stated intervals within this distance, thus ascertaining the sectional area of the stream. The velocity of the water at

the centre and sides must next be ascertained by means of a stop watch and a well shaped float—the distance traversed being accurately measured and set out with pegs. The result will naturally be lineal feet per minute, which can be converted into cubic capacity by multiplying it by the mean of the total number of cross-sections. By again multiplying this result by 6·24—the number of gallons in one cubic foot—and by 1440—the number of minutes in the 24 hours—the daily discharge in gallons is obtained.

If the quality and quantity of water discharged from a spring prove satisfactory, the next step is to construct in its immediate vicinity what is termed a "service" reservoir, which should contain at least a week's supply. The details of such a reservoir will be described in a subsequent paragraph.

With an upland brook—in contradistinction to a spring—the next step, after analysis and gauging, is to be assured that the character and area of gathering ground behind will allow of pure water in sufficient quantity being impounded. A geological knowledge of the site is thus absolutely necessary, for otherwise great expense may be easily incurred in work which may afterwards prove useless.

The damming of a stream produces what is technically known as a "storage" as distinguished from a "service" reservoir. This description of reservoir should contain at least six weeks' supply,

including the daily loss by evaporation, which is estimated at a trifle more than one-tenth of an inch on a hot summer's day.

The most advantageous site for a storage reservoir is one where a comparatively small embankment thrown across a valley forms a reservoir of the necessary capacity, of which only one side (the bottom or lowest side) is artificial, the water being retained within the remaining sides by the rising ground. Too much attention cannot be given to the examination of the actual site, and every possible information must be obtained on this head before the works are commenced, by means of trial shafts or borings, so that the nature of the ground may be accurately ascertained, and any fissures within its area efficiently stopped up. The main feature of a storage reservoir is of course the above-mentioned embankment and its foundation. The latter is technically known as the "trench." This trench, which naturally supports the embankment above, is generally constructed of clay puddle, and is from 8 to 10 feet wide at the surface of the ground. If it is made with concrete, its width may be reduced to 6 feet. It must of course be carried down —no matter what the expense may be—to a depth of at least 10 feet into the nearest solid or impervious stratum beneath. It should be sunk with perpendicular sides, so that the puddle or concrete at the bottom may be of the same width as it is at the surface.

The chief point of the embankment is its core

technically known as the "puddle wall." This wall should be brought up to within at least one foot of the top of the embankment, and it should be at least 8 feet wide at its summit. It should be provided on both sides with a batter of 1 in 12, which batter should extend down to the natural surface of the ground, or, in other words, down to the top of the puddle trench. The clay with which this puddle is made should be spread in layers—about 8 inches or 9 inches thick—well watered and twice cut and trodden. This gives a satisfactory result, although it is necessary sometimes to adopt tempered clay, on account of the difficulty in cutting and treading it between the timber used for supporting the sides. It must not be forgotten that no clay for this puddle should be excavated from behind the trench, that is to say, from the site of the proposed reservoir. The earth used for the outside or skin of the embankment should be carefully selected, and, as with the puddle wall, care must be taken not to excavate anything from the interior of the reservoir, the removal of which might facilitate the access of water to any fissures which may have escaped observation, and thus provide a means of escape for the water intended to be retained in the reservoir. The height of the embankment should never be less than 4 feet above the level of the impounded water. Its surface width may vary to suit individual circumstances, but an average of 10 feet is permissible. The batter on its inner or water side should be 3 to 1, and on the outer or lower side 2 to 1, and

the former must be protected from wash by dry rubble, pitching, brickwork or concrete. The bye-wash or channel for conveying the surplus water from the reservoir, when full, back into its original channel, is also a matter of importance. Its length is naturally dependent on the area of the contributory watershed, and the greatest amount of rain which is likely to fall upon it in any one day; but after a knowledge of these particulars it is easy to calculate the quantity which may, during wet weather, flow over it, which quantity should not if possible exceed a maximum depth of 6 inches. The removal of all brushwood, vegetable matter, peatty or boggy soil is necessary, because prejudice is readily created against the water if any discoloration is noticed in it. When the reservoir has been completed, great care must be taken in filling it, for it is essential that the water should rise as slowly as possible, in order that the inner or water slope of the embankment may gradually settle, otherwise subsidence may occur and the puddle wall, if unsupported, may crack. This is an extra reason why the puddle wall should be constructed in thin layers, so that it may the more readily become consolidated. I have instanced a cross-embankment, as it is usually constructed in England, but it must not be forgotten that on estates where stone is procurable, a more satisfactory result is obtained by its use when properly keyed together, than with puddle and earth.

WATER SUPPLIES BY PUMPING.

When, as is more often the case, neither a spring at sufficient altitude, nor a brook with a suitable gathering ground behind it, can be secured for the supply of water by gravitation, recourse must be had either to a spring out-cropping at a lower level; or to the subterranean water beneath, and, as a consequence, pumping must be resorted to in some form or other.

With a spring, the first thing to do after the usual preliminaries is to construct in its immediate vicinity a small covered underground chamber of either brickwork or concrete, which receptacle should contain at least twenty-four hours' supply. This amount of storage is advisable, in order that there may be a collection of water during the night. By this means not only is a reserve store secured before pumping is commenced the next day, but the drawbacks consequent on the temporary breakdown of machinery are to a great measure overcome. The small room or "station" in which the pumping machinery is fixed, is generally placed immediately over or adjacent to the storage chamber above mentioned.

When underground water is resorted to, it is always advisable that a preliminary boring at the hands of experienced well-sinkers should be made, in order to find out accurately the standing water level beneath. Having ascertained this desideratum, the available quantity of water must next be deter-

mined. For this purpose, in the case of towns, it is the custom to require that continuous pumping should be carried out for fourteen consecutive days and nights, gaugings being frequently taken throughout this period. In the case of mansions or estates, however, such lengthy pumping is perhaps not necessary, and therefore probably one week's day and night pumping or a fortnight's day pumping would suffice. This pumping should be carried out when the springs are at their lowest.

Ordinary Wells.

The sinking of wells from which to obtain the subterranean water is the question which next calls for attention, though the details connected with them need not be lengthily discussed, because the general principles of ordinary well-sinking are now everywhere thoroughly well understood. In all instances their diameter should never be less than 6 feet, 8 feet in the upper lengths being preferable, because with wells of smaller diameter, when pumps are placed within them, the space for the occasional and necessary moving about round the machinery becomes too limited; whilst no more pumps can ever be added in the future should local requirements demand them. Two rows of brickwork laid in cement, backed round where necessary by rubble and concrete, may be said to be the almost universal method of construction in examples such as are now

under consideration, but in treacherous or sewage-polluted soils recourse should be had to cast-iron cylinders instead of brickwork. It is a recognised rule that there should be storage in wells, either in the well itself or in adits leading from it, for at least one day's supply. This storage should of course be below the pumps. In cases where the nearest water-bearing stratum is at a considerable depth below the surface, and where there is sufficient head of water in it to cause the water, after the formation has been pierced, to rise through the impermeable strata into the well and thus regain its level, a borehole is often sunk from the bottom of the well, which is not then carried below the upper or impermeable stratum. These boreholes are of wrought-iron or steel tubes, varying in diameter from 4 inches to 12 inches, and are screwed together and lowered from the surface. They stand for all time and save the expense of a large well of great depth.

Artesian Wells.

There are many instances in rural districts where the consumption of water must always remain comparatively small, where the impermeable upper stratum is of no immeasurable thickness, and the water bearing stratum below is consequently at no extreme depth with, as in the previous instance, high ground behind it so as to form a head for the rising up of the water either to the surface or to a

short distance from it. Under such circumstances an ordinary well need not be constructed, but tubes may be sunk throughout the entire distance within which what are termed borehole pumps may be fixed at a trifling depth below the standing water level. These wells are named Artesian from "Artois" in France, which place is situated in a geological basin where it was first discovered that the water would rise up the tubes until the weight of the column of water therein was equal to the weight of the rock, or in other words, so long as the water can more easily rise up the tube than be pushed onwards through the rock by that which is pressing it from behind.

The Raising of Water.

The various means of raising water are—

Hand Power.—Hand power is certainly the most unsatisfactory and uncertain method of raising water that can be resorted to, for it will generally be found that on occasions, when a house is full of visitors and extra pumping is required, the odd man who is told off for this duty has failed to put in an appearance. The result is that a scarcity of water follows with much discomfort. In my opinion this power can only be economically utilised where the depth from which water is lifted does not exceed 25 feet, the quantity of water daily

consumed is not more than 500 gallons, and when, as a result, the common atmospheric, i.e. the suction or lift pump with its levered handle can be used.

Where the quantity to be raised is comparatively large and the depth considerable, the levered handle must give way to a framed arrangement of gearing, which can be worked by wheel and pinion to allow of the employment of two men. Under such circumstances, however, manual power should, in the interests of efficiency and economy, be abandoned for another motor.

Horse Power.—Horse power is more economical than hand power, unless a horse or donkey is kept or hired for this special purpose, because the animal may be attended to by a boy, and because the time occupied in pumping the required supply is considerably less than with hand power, thus allowing the horse to be otherwise employed during the greater portion of the working day. The eminent engineer, Telford, considered that a man of ordinary strength could exert a force of 15 lbs. at a crane handle moving at the rate of 220 feet per minute, per day of eight hours, while an ordinary horse drawing at the same speed (220 feet per minute) would be able to exert a steady pull of 150 lbs. for eight hours per day, thus $220 \times 150 = 33{,}000$ foot-lbs. per minute. At this rate a horse is equal to ten men. This comparison is instanced because the power to raise 33,000 lbs. to a height of one foot per minute is that which, as is well known, is

generally taken as the datum power of a horse in calculations of the services of different motors. When this form of power is adopted the horse-power arrangement should, where practicable, be from 25 to 50 feet in diameter, though a horse will walk without actual discomfort in a circle of 18 or 20 feet.

Horse power for the raising of water is not to be recommended, because during the last ten years great strides have been made in various other motors, through the instrumentality of which during certain times of the day, when the raising of water is not required, the power may be readily utilised for other purposes, such as the sawing of wood, the cutting of chaff and roots, and the electric lighting of mansions. It may, however, still remain in use as an adjunct to other forms of power to be brought into operation should the primary motor fail.

Wind Power.—As with horse power so with wind power, both have given way during the last ten years to other motors. Still, the utilisation of wind power for pumping is naturally attractive to the economical mind, and, as windmills have been used up to the present day from time immemorial, their occasional adoption will continue. The extreme number of days in the year on which the wind might not have sufficient power to perform the required duty, was stated by my late father, who made a study of the question, to be a little less than

a hundred, but any estimate to be of value must greatly depend on local circumstances, and therefore this calculation must be taken with reservation. Under any circumstances, where wind power is adopted, it must either be associated with a larger service reservoir than would otherwise be the case, in order to compensate for very calm days, or the gearing connected with the windmill must be so arranged that an alternative power may be used, i.e. horse or portable steam. The best form of windmills are those known as the Halliday Geared Windmills and others of similar type. They are of light iron framework, fitted with ordinary sails; but if used it must not be forgotten that the actual power obtainable is not equal to their stated duty; that is to say, theoretically speaking, if a 4 horse-power is required an 8 horse-power windmill must be purchased.

Water Power.—One of the readiest means for raising water from running streams or springs is water itself. Where it exists in quality sufficiently pure for domestic purposes, and in sufficient quantity to be used as a power at the same time, the hydraulic ram will be found to be the cheapest and best motor, but it must be remembered that the elevation to which the water has to be raised must not be too great, otherwise repairs to the working parts will be frequently needed. An ordinary 4-inch ram, with a 1-inch rising main with a fall of, say, 10 feet and with a flow of water to it of 20 gallons

a minute, will raise 2 gallons per minute, or 2880 gallons in twenty-four hours, from 90 to 100 feet in height to a distance of half a mile.

The principle of the ram is different to that of other hydraulic machinery, as by concentrating into a small quantity the force accumulated by a larger body, the small quantity is raised to the required height.

As the hydraulic ram differs in its principle of action from all other means of raising water, so its useful effect varies according to a different law. For instance, when the height to which it is desired to raise the water amounts, as above, to ten times the fall, the water raised will be one-tenth of the working power, whilst with an increased lift the result will be less. Under many circumstances it may be said that the ram is very suitable for the water supply of mansions, for it performs its task with very little care on the part of the owner, who has only to see that the water is strained through a grating before passing through the ram, and that it is emptied or protected during hard frost.

Rams to pump clean water by the employment of the force of dirty water cannot be recommended, because they require more frequent attention than a small water-wheel and many other motors.

The Water Wheel.—As the principle of the water wheel is so well understood, it need only be briefly referred to. In doing so, however, its importance in rural water supply must not be

under-estimated, because there are many institutions and country mansions in close proximity to running streams, especially in the flat districts of England, the water of which may by means of this wheel be favourably and inexpensively employed for the raising of water from wells sunk in proximity to such streams. Water wheels, for obvious reasons, are not to be depended upon in cases where the stream is liable to frequent floods, because by the uprising water their action is impeded, if not stopped altogether.

During recent years the water wheel has undergone many improvements, and wood has given way in its construction to iron and other metal.

The wheel known as the overshot wheel gives a greater power than any other form where the fall is comparatively great and the quantity of water available to work it is small. Where, as in the case of the majority of instances, the river or stream at command has a slight inclination, and where, therefore, the overshot wheel cannot be adopted, the undershot wheel will be found serviceable. Between the two the breast wheel may be turned to account.

Comparing the undershot wheel with the overshot, the relative efficiency of the latter may be taken to be about double that of the former, while the breast wheel will yield a result rather greater than the mean of the two.

The Turbine.—Turbines are encased wheels of very much smaller size of course than water wheels

and are most applicable either when there is a considerable head, or a considerable volume, of water above them, the necessary quantity of which is conveyed to them by a special line of pipes diverted from the stream or river. They are provided with a number of buckets so arranged that the stream directed upon them may have the best effect. As they frequently have to work with a varying quantity of water, it is of extreme importance that they should be so designed as to give the highest possible efficiency with both the maximum and minimum supply. Seventy-five per cent. is generally reckoned as the efficiency of a good turbine. The shafts of turbines may be vertical, horizontal, or inclined in any position. The latter method, however, increases friction, and is therefore, if possible, to be avoided.

Until recent years turbines have been constructed to receive their supply from above, but this arrangement renders them difficult of access, and thus trouble and inconvenience may be caused. For this reason many makers have lately constructed turbines, so to speak, upside down, that is to say, they are fixed upon an inverted syphon so that the supply of water enters from below. By this means their working parts can be readily seen and inspected without the least inconvenience.

There are many good makers of turbines in this country, but their design must in every instance be made to suit local circumstances. If there is plenty of water with a good head at command, and the

supply does not vary, a comparatively cheap turbine will do all that is necessary; whereas, if the supply is limited, and, as a consequence, more elaborate machinery is required to obtain a good result, of course more expense must be incurred; whilst, if the supply is variable, extra care must be taken in the arrangements for contracting the guide passages, so that a limited quantity of water produces no diminution of efficiency.

Turbines cost less than water wheels, whilst their efficiency is greater. Under these circumstances, therefore, wherever a turbine is applicable it should certainly be adopted.

Hot-Air Power.—Up to within four or five years ago hot air took a prominent place as a motor for the raising of water for domestic purposes where small power only was required. This class of engine is certainly perfectly safe, because, as in the case of gas engines, explosion is impossible. They are extremely simple in construction, noiseless in action, and require no experienced engineer to look after them. They also possess the benefit of being economical in maintenance, because coke is used in place of coal. Their sizes, however, only range from ¼ horse-power to 2 horse-power, and the latter will deliver into an ordinary house cistern 1000 gallons per hour, whilst the former will discharge 200 gallons in the same time. Their action is very simple, the power being generated by the heating of air in cylinders. The same air is used

continuously, there being neither influx nor escape, it being merely shifted from one cylinder to another, whilst the cylinders are kept cool by means of a water-jacket. Still, experience has proved that their working parts frequently require repair, and that they cannot be left unattended for any length of time. These two drawbacks, in addition to the fact that their size is very limited, have been the cause of their gradually dropping into disuse.

Gas Power.—Until recently, gas engines were very frequently used for the supply of water in country districts, but since the introduction of oil engines and other more modern inventions they are not now so common. The reason of this is that, even when there is an available public supply of gas, the expense entailed in its use is generally very heavy, which disadvantage even applies, though in a less degree, when the gas is made on the premises by means of the Dowson generating plant.

Gas engines undoubtedly possess certain advantages in that they require when once started little attention, whilst in addition, owing to the absence of boilers, all chance of explosion is avoided, and, as there is no fire, there is naturally no nuisance from smoke.

The consumption of gas may be taken to be from 18 to 21 cubic feet per horse-power per hour, and the sizes of engines generally used are from ½ horse-power to 16 horse-power.

Oil Power.—One of the most modern forms of motor for raising water, and one of the best and most economical, is the mineral oil engine. For practical purposes this class of engine may be said to vary from 1¼ brake horse-power to 14 brake horse-power, although they are advertised as being made of far greater size. They are simple in construction, reliable in action and economical in maintenance, the consumption of oil being from 1 pint to 1⅕th pint per brake horse-power per hour, whilst the cost of the oil used may be taken at 6*d.* per gallon. It will thus be seen that their cost of maintenance is far less than that of a gas engine, whilst they do their work equally well and are just as useful for the performance of other supplementary duties. Practically no attendance, skilled or otherwise, is required after starting for a day's work, whilst there is absolutely no danger connected with them.

As far as my experience has gone, Messrs. Priestman of London and Messrs. Blackstone of Stamford are amongst the best makers, though there are doubtless many others equally good. There is one point, however, in connection with the Blackstone engine which should be noticed, and that is that it can be converted from oil to gas, and *vice versâ* in about five minutes.

Electricity.—Where an electric lighting installation has been provided, advantage may be taken to utilise the generated electrical energy for the raising

of water. A cable or overhead wire (the latter being cheaper) can be carried from the battery to the pumps. An electric motor, which is a small, compact and comparatively inexpensive arrangement for converting electricity into power, can then be fixed upon a bracket on the pump frame, the pumps being driven by worm gearing actuated by the motor. This arrangement will be found most effective, whilst it can also be utilised at the same time for chaff-cutting and dairy purposes.*

Compressed-Air Power.—The method of raising water by compressed air is applicable in the case of a bore-hole, down which two separate pipes of different sizes are inserted. The first or larger of these two pipes is from 4 inches to 6 inches in diameter, according to the volume of water to be raised and to the rate of collection of the underground supply, and it is lowered down the bore-hole to a given distance below the standing water level. The second pipe is of smaller diameter (1 inch or 1½ inch), is lowered to the same depth, and at its base is bent upwards into the larger pipe, which thus virtually becomes a rising main. The compressed air is driven down the small pipe and forces the water up the rising main to the required height.

Where compressed air is resorted to it must

* A motor requires no engineer and but little attention. It is started and stopped promptly by the simple turning of a switch, and only consumes current when running and in proportion to the work which it performs.

not be forgotten that the bore-hole must be carried down beyond the customary depth, so as to ensure the constant immersion of the pipes under all circumstances. Otherwise successful results will not be obtained.

Free air can be compressed to the required pressure (*a*) by means of a small oil engine and compressor situated either at the top of the bore-pipe or adjacent thereto; (*b*) by means of an electric motor and compressor, the motor being driven by electricity as previously described; and (*c*) by means of a water-wheel or turbine, if this form of power is to be obtained on the estate.

The great advantage of using compresed air for the raising of water is the fact that by its adoption pumps are dispensed with, and consequently all repairs to valves, buckets and gearing are avoided; whilst the whole of the machinery connected with it is above ground, and therefore easily accessible for inspection. The "air lift," as it is generally termed, has within the last few years been used with great success in America, and it is now making considerable progress in this country.

Steam Power.—My remarks upon steam power have been left until last, because generally it need not be adopted. Where, however, a greater power is required than about a 16 or 20 brake horse-power engine, steam may be satisfactorily and even economically resorted to. Steam has the disadvantage of not only involving a comparatively heavy initial

outlay, but of requiring continuous skilled attendance in maintenance, and also of necessitating a constant expenditure in fuel, although this latter item may in many cases to a certain extent be reduced by the provision of extra large reservoirs or tanks, in which case the machinery need only be brought into use two or three times a week instead of daily. Moreover, a portable engine may be very often advantageously adopted, which can be readily attached to, or detached from, the pumping arrangements, and used for a perfectly different purpose.

PUMPS.

Much need not be said with regard to pumps, inasmuch as, like the steam engine, their constructive principles ought to be well known, moreover they have not materially altered during the last twenty years. They may be divided into the following classes.

(*a*) The atmospheric or common suction pump.
(*b*) The lift and force pump in its various forms.
(*c*) The centrifugal pump.

Class (*a*).—In practice it has been found that a depth of from 24 to 26 feet is the maximum limit from which water can be drawn by this description of pump, which is of the simplest character and which is of course worked by one man. These pumps can be placed in any position, either outside or within the dwelling, and erected over sinks, or any

other place, where space and height will allow of it. They are especially applicable for the raising of water from rain or soft-water tanks.

Class (*b*).—When the depth of 26 feet is exceeded, or when it is necessary to raise the water to any height above ground level, additional forcing power must be resorted to, and it is then that the lift and force pump comes into use.

These pumps are either worked by one or two men as circumstances require, but with deep wells and high lifts (which are more often than not the unavoidable adjuncts of water supply) they are actuated by the various motors previously described.

There are many different modifications of this description of pump.

1. The ram pump.
2. The bucket pump.
3. The bucket and plunger pump.
4. The solid piston pump.

One or other of the above is generally applicable for an estate or mansion.

Class (*c*).—The use of the centrifugal pump has not increased within the last ten or fifteen years, as it is only applicable to lifts up to within about 20 feet. Its name explains its action. It is very compact, simple in construction, and is easily connected to any description of motor, but the limits of its power, as it is unable to force, preclude it from much consideration for the object in view.

Service Reservoirs, Etc.

Having settled upon the form of motor, the water has to be raised through a rising main into a "Service" reservoir if there is on the estate a convenient site of sufficient altitude to command the mansion, homesteads and out-buildings. This reservoir should contain at least one week's supply. It may be built either of concrete or brickwork, lined with cement on the inside up to the water level so as to be perfectly water-tight. It is generally constructed (in order to save expense) half in the ground and half out, arches being built to form the cover and the whole being fenced round.

In order to render its periodical cleaning an easy matter, the reservoir should be built in duplicate, a penstock being placed in the division wall so that one half may be cut off from the other at will.

Small ventilators should be provided along the roof so as to allow of the circulation of air. The necessary valves and penstocks require no comment as they are all of a simple character.

Generally speaking an electric, or float, connection between the pumping station and the reservoir is unnecessary, because experience very soon teaches the engine driver, when he has once grasped how much pumping it takes to fill a foot of the reservoir, how long he has to pump day by day in order to satisfy all requirements.

Failing a suitable site for a reservoir, the water should be raised into a water tower, the tanks within

containing at least three days' supply. If possible, three separate tanks are advisable; the highest for fire service, the second or middle for house purposes, and the third or bottom for use in the stables and gardens. Intercommunication should be provided between the three, so that occasionally, or in case of fire, water may be passed from one to the other. Of course it is not absolutely necessary to provide three tanks, because two may perhaps answer the purpose aimed at, whilst in some cases even one may suffice; but the first-mentioned method is decidedly the best, because it is always advisable to have a separate fire main under permanently high pressure. The intervening space between the tanks may be profitably utilised for the storage of apples, potatoes, roots, etc.

The third alternative, when neither the first nor second scheme is feasible, is to provide tanks, either on the roof of the mansion or over the stables, which may be placed on steel joists, of course supported by main walls. Under such circumstances it is impossible to settle the amount of storage. It should, needless to say, be as copious as possible, care being taken that the weight of the impounded water is not so great as to endanger the safety of the structure. In many cases, as will be obvious, it will be necessary to erect these tanks in the open, and therefore under such circumstances great care must be taken to protect them from frost. This can be done by means of double wood casing with sawdust packing in between.

The Storage of Rain Water.

Most people have realised the great desirability of storing rain water for domestic use, though few have taken advantage of the ready means of doing so.

Rain water, as is well known, is most valuable for certain descriptions of cooking, most agreeable for washing, and much sought after in establishments where there are nurseries and children. The value, therefore, of its collection from clean roofs or other surfaces, and subsequent storage, can hardly be over-estimated.

There are dwellings, institutions and mansions in this country without end, where the extent of roofing exceeds half an acre or 80 poles, and very many more where it exceeds a quarter of an acre or 40 poles. Thousands of ordinary houses cover 10 poles, whilst a rural labourer's cottage generally covers 2½ poles. Taking for example an ordinary mansion and out-buildings, the roofs of which cover a quarter of an acre, it will be found that if the total rainfall falling on the roofs were preserved, it would amount in a year with a rainfall of 24 inches to 135,907 gallons, which quantity is enough to supply more than twenty-four people at 15 gallons per head per day with water for a whole year. Of course in practice it is impossible to preserve this large amount, but a considerable portion of it may be saved, with advantage and profit to all concerned.

The sizes of underground tanks for the reception and conservation of rain water should be as large as is in each case advisable. They are built below ground, constructed of either brickwork laid in cement, or of concrete faced with cement rendering, and should be in duplicate, so that, when required, they may be readily cleaned out half at a time. The water from the roofs is conveyed to them by means of the ordinary down pipes, which at their base should discharge over gullies provided with galvanised cast-iron gratings to prevent the entrance of leaves, vegetable or other polluting matter. From the gullies the rain water flows by means of small stoneware pipes, jointed with cement, to the tanks, before entering which it should be made to pass through a small accessible filter, shaped somewhat like a box, the material in which should be sand and broken stones. This filter should also be constructed in duplicate, so that one portion may be cleaned at a time without arresting the flow of water. Of course the water is raised from the tanks by means of the ordinary hand pump into cisterns placed wherever it may be desired within the residence.

The value of rain water in cases where other water is difficult to obtain is very great; and in one or two instances where it was impracticable to satisfactorily provide a supply, from either spring or subterranean water, I have had recourse to it with the most satisfactory results. As a gathering ground, I selected half an acre of suitable land

situated at a higher level than the mansion, making it thoroughly impervious by means of a concrete floor with cement surface, and fencing it off so as to avoid any possible contamination from cattle, etc. Underneath I constructed a large service reservoir, thus securing most of the rain falling on the impervious surface above, which was at certain seasons of the year used as tennis courts. By this means an efficient and agreeable water supply was obtained sufficient for all purposes.

Rising and Service Mains.

Rising and service mains are generally of cast-iron pipes jointed with yarn and lead, their sizes of course being determined by the engineer who is responsible for the scheme. In order to protect their contents from frost, the depth from the surface of the ground to the top of the socket should never be less than 2 feet 9 inches. The pipes should be of uniform bore and thickness throughout, and of the best British grey metal, coated inside and out with Dr. Angus Smith's preparation, which is the usual precaution taken to prevent oxidisation. This solution is a bituminous preparation in which the pipes are dipped when at a certain heat.

It should not be forgotten that air valves should always be provided along the lines of the mains at summits where the course is undulatory and the main falls away in both directions. The sluice valves and hydrants should always be of the best

quality, being tested to the requisite pressure before delivery.

There is no class of building in this country which is more exposed to the ravages of fire than a country mansion. Wherever possible, therefore, a fire main should be laid both outside and inside it. The outside main should be carried all round the mansion, and not only along one side of it, so as to secure a complete circuit of the water, and the inside main should be continued up the centre of the house to the topmost bedroom floor. Outside hydrants should be placed at suitable distances apart, and inside hydrants on each landing. The hose used outside should be of flexible leather cased with copper wire, which must be kept soft and pliable by the occasional application of tallow or dubbing, and with the fittings it must be kept coiled up in a well ventilated dry place. The hose used inside, which is not subject to such rough usage as the outside, may be of canvas. The fire appliances should be kept on each landing, perfectly separate from the outdoor fittings, and be examined and tested every three months.

It is always advisable that servants be periodically drilled in fire exercise.

House Cisterns.

It is very unsatisfactory to be obliged to acknowledge that after obtaining water of a potable character from a stream or well, and after con-

serving it in tanks, reservoirs, etc., it often loses its good qualities in the house cisterns into which it is raised previous to distribution. Cisterns should be placed in clean and accessible positions, and never in bedrooms. They should be securely covered over, carefully protected from frost and changes of temperature by being, where necessary, enclosed within some non-conducting substance, and the overflow should always be taken directly into the open air. It is an advantage to provide, if possible, small separate cisterns for drinking water.

No cistern should be allowed to remain for more than three months without being thoroughly cleaned.

The best of all cisterns are those made of slate or galvanised iron. Lead and zinc lined cisterns are both decidedly objectionable, though I consider that lead is often condemned when the effect complained of is due rather to the action of certain impure water upon the lead than *vice versâ*.

Filtration of Water.

In all country districts, provided that a satisfactory source of supply has been obtained, domestic filtration is in my opinion generally unnecessary except in the case of rain water, for I maintain that if such water when drunk by the individual is impure, this impurity has in all probability been caused by contamination within the house cistern.

Moreover, the generality of the filters now before the public are placed inside the cisterns. They are, therefore, continuously under water, and merely become nests for the growth of germs and organisms, producing the very reverse effect to that intended. If a filter is resorted to at all, it should be what is termed an aërating filter, that is to say, the filtering material should be alternately subjected to the action of air and water. The filtering material must be easily accessible, and never cemented down, so that it may be readily taken out of the filter and cleaned at least once a quarter.

Finally, it must not be forgotten with regard to domestic filtration that much more depends on the *aëration* of the material than on the *character* of the material itself, and that no water which is radically impure to start with can subsequently be made chemically potable by filtration of any description.

THE WATER DIVINER.

I cannot conclude my remarks upon water supply without referring to the work of the dowser or water diviner, who in this early part of the twentieth century is looked up to in many quarters, especially by ladies who are the owners of estates.

It cannot be denied that water diviners have by means of a twig been successful in many instances in finding water; but common sense tells one that there can be no direct connection between under-

ground water and the motion of the twig which the dowser holds in his hands, from the fact that by the aid of a twig in olden days the dowser discovered ores of precious metals, buried coins, and other treasures, lost boundaries, strayed cattle, and even hidden criminals. It is true that certain dowsers have a genuine faculty for discovering water, but their success is probably only due to shrewd observation, and to the conscious or unconscious detection of the surface signs of underground water.

The water diviner always asserts that he does not concern himself with the nature of the ground, but that he is solely guided by the twitching of the twig which he holds in his hands. If this is so, how is it, as the President of the Institution of Civil Engineers has recently pointed out, that there never have been any blind diviners, although water finding by this process has been in existence for more than four centuries?

SEWERAGE.

BEFORE describing in detail the sewerage of country houses, I desire to make a few preliminary remarks upon certain points which, although they primarily concern the architect more than the engineer, yet have considerable influence upon the health of the individual.

THE SITE.

Aspect and site have each their bearing upon salubrity and equality of temperature, but neither the one nor the other has an influence so great upon humanity as the condition of the soil beneath and surrounding the house. Dryness of soil is particularly essential to health, and the engineer, architect or surveyor, before deciding upon the site for a residence, has power by appropriate under-drainage to render a wet and polluted soil both dry and wholesome. Published reports have shown the remarkable manner in which decrease in death from consumption has followed the drying of the subsoil; and there can be no doubt that where the standing water level in the ground does not

naturally lie at such a depth as to be beyond the power of injury, the professional adviser may effect that object artificially by means of under-drainage.

When it is remembered that the death-rate of England and Wales, due to consumption alone, has been shown by the Registrar-General to be about one-ninth of the total, and when it is realised that the deaths caused by that disease in fifteen English towns where under-drainage has been systematically attempted, have fallen according to published statistics from between 49 to 11 per cent., owing to the removal of the subsoil water, no one can fail to realise the great desirability of a thoroughly dry site.

As I am now referring to the drying of the site by means of drainage, I ought to perhaps explain the real difference between a drain and a sewer.

The word drain is derived from the French word "Trainer"—to draw—and the real meaning of the original word is a channel to draw together water by degrees: the very reverse of the object of a sewer, a word also derived from the French "issuer," the precise meaning of which is a conduit for the rapid discharge of water. Therefore, whilst drains should draw into them as much water as possible, sewers ought to be water-tight, for if they are not so, the same openings which admit the subsoil water into them will allow the sewage to escape out of them into the surrounding soil.

Mode of Under-Drainage.

The method of under-drainage necessary to lower the water in wet lands varies of course with the character of the subsoil.

In free soils one single drain will often lower at very little expense the water level of a very wide area. In such a character of soil no advantage is gained by multiplying drains beyond the minimum number which will effect the desired object. In heavy soils, however, numerous drains are necessary to overpower the retentive properties which such soils possess, and the greater the number the better will that purpose be fulfilled. All drains should be made secure against the entry of roots of trees and shrubs, and the accumulation of peroxide of iron and other impediments. This can be done by carefully jointing the pipes with tarred gaskin and cement when passing through places subject to such obstructions.

In waterlogged free soils it is very seldom necessary to lay these drains beneath the actual site of a house, because, as previously stated, the drawing capability of a drain extends over a wide area; but in clay soils such is not the case, and care then has to be taken to produce by the complete aëration of the subsoil an uniform disintegration throughout, which will prevent expansion and contraction under different conditions of the atmosphere, and so avoid any injurious effect on the future superstructure.

Concrete Floors and Walls, etc.

When building houses provided with basements, every care must be taken to prevent dampness rising up under the basement floors or up the walls. To prevent the former evil, therefore it, is advisable to lay them on a bed of concrete extending over the whole base from outside wall to outside wall. This concrete floor not only prevents dampness and ground air from rising up from the underlying soil, but it will also prevent any liquid refuse from sinking down into it.

To prevent moisture from rising up the walls of a house it is the universal custom, except when building on the rock, to construct them upon a foundation of concrete, and to provide a damp course consisting of an impervious layer of bitumen —a mineral substance of a resinous nature—cement, slate, or asphalt, between the courses of brickwork or layers of stone work. This damp course should be placed immediately above the ground level; but below the joists of the floor; and the bed of concrete under the basement should be to the cellars and rooms above them what the damp course is to the walls.

All houses with basements should be built with an area between the surrounding ground and the walls. There should be no exception to this rule; whilst in clay soils, cellars and basements should be avoided altogether. Indeed, houses built

on clay should be well raised above ground level, with free ventilation between the surface of the ground and the ground floor.

Dripping roofs are a very common cause of dampness. Many a dwelling (without a basement floor and otherwise dry and healthy) is rendered quite unfit for human habitation by the aged or infirm from this cause alone, and most people must have observed that the rain falling on the roofs of country mansions is often allowed to drip on to and sink into the ground in immediate contact with the walls, owing to the absence of, or bad condition of, the eave-troughs and down pipes. It is frequently owing to the absence of the precautionary measures to which I have alluded that dry rot (which traces its names rather to the effect produced than to the cause) takes place. Dry rot is generated by a damp, close, unventilated and dark atmosphere; and when once in existence spreads with great activity and vigour through timber and walls in all situations, dry or damp, light or dark.

I have hitherto only instanced cases where the house is not yet built, but in cases where it is in existence and found to be damp owing to the absence of a damp course, the only effectual course is to underpin the walls and put one in by easy stages. Of course some time elapses before any beneficial result is manifested.

The practice of putting laminated lead over the walls of a damp house before papering should be

avoided, if possible, because it merely produces satisfactory results for a time, whilst really only driving the damp inwards without in the slightest degree eradicating the evil.

The Definition of the Word Sewage.

Sewage may be devided into two parts :—

Firstly.—The refuse of which the medium of removal is water ; and

Secondly.—Solid refuse and garbage.

The first or liquid refuse is discharged by the sewer ; the second or solid refuse must be removed by hand and either burnt or dug into the ground.

It is not necessary to again refer to the second portion beyond merely saying that the receptacles used for its storage must always be kept covered over, and that they should be capable of an easy and ready removal, which should be frequently and regularly carried out by some responsible servant.

The Sewer and its Branches.

The sewer which connects the mansion either with private sewage disposal works or with an adjoining public system of sewerage, should conform to the following rules. It should be constructed of stoneware pipes of the best manufacture, jointed in such a manner as to form a perfectly water-tight conduit. Tarred gaskin with cement, and not "special patent joints," are the best materials for

rendering joints water-tight; and under no circumstances should only puddle clay be used, because this last named material never secures a really perfect joint in itself. It proves, moreover, especially faulty where pipes are laid in a dry soil, and where, as a consequence, drought and evaporation soon cause the clay to crack. Clay likewise affords no resistance to the intrusion of the roots of shrubs and trees, which will very soon make their way through it in their search after moisture.

The advantages of a water-tight sewer must commend themselves when it is remembered that if sewage is able to find its way out of an imperfectly constructed sewer, the sediment left behind will soon collect and ultimately choke it up.

A sewer should in no case—where it can possibly be avoided—pass under a house. Where, however, an outside course is impossible, cast-iron pipes jointed with lead should be laid (in place of stoneware) from outside to outside, with means of inspection at both the lower and upper ends. The course of all sewers should be as direct as possible, but where one direct line cannot be adopted it should consist of straight lengths from angle point to angle point, at each of which an inspection chamber should be provided. Care should be taken, by the use of concrete or by other expedients, to prevent the sinking of any of the pipes in treacherous soils, and to sustain true lines of continuity. All sewers should be laid with such an inclination as will secure for their contents a velocity of not less than

2½ feet, and not more than 10 feet per second. If, however, a less velocity than 2½ feet can only be obtained, pipes of the very best internal glaze must be used in order to prevent the adhesion of solid matters to their sides. A specially effective means of flushing must at the same time be provided.

No main sewer need exceed 6 inches in diameter, except in very large establishments or public institutions, when 8-inch or 9-inch pipes may perhaps better answer the purpose. Branch sewers need only as a rule be 4 inches in diameter. Smaller pipes should not be used.

It is always necessary, no matter what ultimately becomes of the sewage, to disconnect the residence at, or immediately below, the point of the lowest house connection from the length of sewer beyond, in order to prevent the uprising and escape of sewer gas into the dwelling. This is effected by means of a small chamber—say 3 feet by 2 feet in size—built of brickwork laid in cement, and provided with a syphon pipe upon its lower side. A cleaning eye renders this syphon accessible from the chamber, and thus there is no danger of its becoming choked up. Disconnecting chambers are usually provided with a hinged cast-iron cover, so that no length of time need be occupied in their examination.

As previously stated, inspection chambers, which are merely small chambers built in a like manner to the disconnecting chamber but without the syphon, should be constructed at all angles, as

well as at as many points as possible where branches join the main. The provision of these inspection chambers renders the examination and rodding of the system a perfectly easy matter.

All sewers above the disconnecting chamber should be periodically tested with water to a head of at least 2 feet. If this is done in section any leakage can soon be localised and stopped.

The great advisability of being able to readily flush out a system of house sewers is very often lost sight of. Automatic flushing cisterns, containing at least 25 gallons and preferably 50 gallons, should be fixed at the summits of all branch sewers where there is any uncertainty as to the daily flow of water along them. As the site of these cisterns is generally an exposed position, they must always be carefully protected from frost.

VENTILATION.

The ventilation of a house sewerage system is a most important item. The best method of affording thorough ventilation is to provide an air inlet in connection with the disconnecting chamber immediately above the syphon pipe previously referred to, and to carry all soil pipes up to and above the roof so as to ensure outlets for the foul air. If the length of any branch sewer is great, it is advisable to have a special ventilating pipe at its summit, which should be carried up in the same

manner as the soil-pipe ventilators. These ventilators may be of either cast iron or lead (as may be desired), but their diameter should never be less than 4 inches. By this method of ventilation a constant current of air is secured throughout the system, and no danger can arise from sewer gas. Revolving cowls and other special devices which readily get out of order, should never be fixed at the top of ventilators. What is termed a "wire bonnet" is all that is necessary.

Soil Pipes.

Soil pipes are those pipes which receive the discharges from water-closets. They should never be less than 4 inches in diameter. This size, however, need not be exceeded except in the case of very large houses where there are more than half-a-dozen water-closets upon one stack of pipes. This practically never occurs, except in large hotels or warehouses. All soil pipes should be round in shape, as they are then more self-cleansing, and not so liable to become foul as square or oblong pipes. They may be made either of lead or of iron, but lead is far preferable to iron, because it is smoother, cleaner, closer in texture, and consequently more durable. Moreover, lead can be bent to suit any position, whilst it does not occupy so much room as iron. Soil pipes should always be of drawn and not seamed lead, and never of less

weight than 8 lbs. to the superficial foot. Wherever possible they should be carried up outside a house, and should be directly connected with the house sewer by means of an easy bend without the intervention of any trap whatever at their base. Soil pipes should be carried up to and above the roof, as previously stated, for the sake of ventilation, and the pipe should be of the same material and diameter throughout its entire length, that is to say, its size should never be curtailed in the upper or ventilating portions. If it is absolutely impossible to place a soil pipe outside, it should be fixed inside in the specially prepared chase of a wall, which chase should be accessible throughout, being covered either with wood casing with hinged doors, or with movable casing.

It must not be forgotten that when two or more water-closets—one above the other—are connected with the same soil pipe, an anti-syphonage pipe from the closet trap of the lowest water-closet must be carried up the wall practically following the same course as the soil pipe, and all the traps of the closets above must be joined to it. This anti-syphonage pipe can be connected with the soil pipe at any suitable point above the uppermost water-closet. It should be of drawn lead about 2½ inches in diameter. The provision of such a pipe prevents the possibility of the traps of upper water-closets being emptied of water, i.e. syphoned by the downward rush of air when a lower water-closet is being used. Except this precaution is taken, sewer gas can enter the house through any trap thus emptied.

The condition of soil pipes should always be tested periodically, i.e. their air-tight condition should be ascertained at regular intervals of time. This testing is carried out by means of smoke in the following manner:—

Smoke is applied under pressure at the inspection chamber nearest to the soil pipe, the tube conveying it being inserted upwards into the house sewer, and clayed round or protected so that the smoke cannot descend but must ascend. After filling the underground pipes and meeting with resistance at the several gullies connected with them, it readily ascends the soil pipes, which, as I have previously stated, should not be trapped at their base. The soil-pipe is plugged at its summit, and thus, as pressure increases, if the joints are faulty, the smoke can soon be seen to escape into the outer air, or can be smelt within the residence.

Testing is a matter of importance, because soil pipes in their upward course must of necessity pass in close proximity to bedroom and other windows.

The Waste Pipes from Housemaid's Sinks.

Where housemaid's or slop sinks are used, their waste pipes should be treated in a similar manner to soil pipes, and be of the same material, except that they may be of less diameter, that is to say, pipes 3 inches in diameter will generally suffice.

WATER-CLOSETS.

Water-closets should always be placed next an external wall, so as to secure ample ventilation and light. They should be lofty and airy, and for the sake of privacy should, if possible, have a small lobby at their entrance. The old pan closet, with its large container, which was so common in bygone days, has now for some years past been discarded, as it is merely a foul receptacle for the accumulation of filth. Numerous valve closets have since come into favour, and many of them are most excellent both in design and character. It must not be forgotten, however, that valve closets require careful usage, for without care, owing to the somewhat intricate arrangement of their working parts, they soon get out of order and thus entail recurring expense. In my opinion the valveless closets which are now being greatly adopted are preferable, as they are far more simple in construction. The best closet of this sort is that known as the wash-down pedestal. I prefer this description of closet because no wooden framework beyond the actual seat is necessary. Everything is exposed to view, and therefore leakage or breakage is easily detectable. They may be of such ornamental pattern as may be desired. All water-closets should be provided with water from a separate cistern placed above them, which should contain at least 2½ gallons. They should likewise be provided with a lead tray beneath, with its waste pipe carried into the open air, so that

all possibility of damage to the ceiling below by leakage may be prevented.

Servants' water-closets may be of the same type as the general house closet. They can be obtained at a moderate figure, as there need be no ornamentation about them.

It is always advisable that closets should be provided with hinged seats to be raised at will. This description of seat renders the provision of urinals and housemaid's sinks unnecessary, and is of great advantage.

EARTH-CLOSETS.

Much need not be said about earth-closets, which are only advisable for the use of men, and which are usually placed in some secluded corner outside the house or out-buildings, because they are most simple in construction. Care must always be taken that the earth to be used is well dried before being placed in the receptacle above, or beside, the closet, whilst it is always advisable that the container beneath should run on wheels, so that it can be easily placed in and out of position and the contents readily removed for use in the garden.

SINKS.

Scullery and pantry sinks, which are generally either of wood lined with lead, stone, or of enamelled stoneware, should always be provided with lead waste pipes 2 inches in diameter, so that the water

poured down them may readily flow away. These waste pipes should discharge directly into the open air over the gratings of gullies, which gullies are of course directly connected with the sewerage system. If the length of waste pipe between sink and external wall is long, an elbow trap with inspection cap should be provided along its course immediately below the sink. This trap prevents the smell from the accumulated grease from entering the dwelling.

In my opinion the use of fat traps (the square or oblong stoneware receptacles placed beneath the floor which up till the last few years were greatly recommended as a means of arresting the fat daily discharged from scullery sinks) should be avoided, because it is far preferable, even in the case of sculleries in very large houses where there is a great deal of cooking, and a corresponding abundant discharge of semi-liquid fat, to treat the waste pipes as described, and to discharge them immediately over gullies without any intervening receptacle for deposit. A flushing tank placed above and in proximity to these sinks will thoroughly flush out the waste pipe and gully, quickly removing all vestiges of fat and conveying it down with rapidity to the site of disposal.

BATHS.

Baths, of which in large houses there should be one on every upstairs floor, may be of either

enamelled iron, copper or porcelain. They should be open all round and not encased in woodwork. They should also be provided with a lead tray beneath, the waste pipe from which should be carried into the open air, whilst the discharge pipe from the bath should pass through an external wall to empty its contents into the head of a down pipe, at the base of which should be a gully in direct communication with the sewer. With this arrangement the entrance of sewer gas into the house is impossible.

LAVATORIES.

The waste pipes from lavatory basins should be treated in the same way as the waste pipes of sinks, those on the upper floors being turned where possible into the same down pipes as the bath wastes.

Tip-up lavatories should always be avoided, inasmuch as they harbour the retention of stale soap suds. Moreover, the contents of the basin are discharged so suddenly into the waste pipe that they are liable to unsyphon the traps both above and beneath except they are especially ventilated.

STABLES.

The sewerage of stables next claims attention. In all details such as water-closets, earth-closets, draw-off taps and gullies it should be similar to that of residences; and it is therefore merely with regard to the best method that can be adopted for

the effective and rapid discharge of the dirty liquid from stalls and loose boxes, that we need concern ourselves.

In my opinion the use of the old fashioned trapped horse and mare pots should be avoided, and in their place, and the buried inaccessible pipes connected with them, semi-circular small open channels covered by movable galvanised iron gratings fixed flush with the floor of the stall or loose box should be substituted. With each box or stall this channel is placed somewhere near the centre, the floor on each side being sloped slightly towards it. When the stable is cleaned out by the groom, or stable boy, all that he has to do is to remove the short lengths of gratings and swill the channel down with water, subsequently of course replacing the gratings. A main channel of similar construction should be laid down the central gangway, the branch channels being connected with it in the ordinary manner. At the upper end of this main channel a flushing tank should be placed of the same capacity as an ordinary house flushing tank. By this means the entire system can be flushed out every day in a very short time.

In large stables it may be advisable (contrary to what I have recommended in the case of a mansion) to cut off or intercept their sewerage system from the sewer outside. This can be generally done in the stable yard by means of what is known as a stable interceptor. This interceptor is made of cast iron, and forms a small, easily acces-

sible trap with a box fitted inside it. This box is placed at the bottom, and can be readily raised so that straw, or any other material, which may have inadvertently been swilled down from the stables, is arrested, and then readily removed. The use of this interceptor is mentioned because it is a known fact that stoppages occur more frequently in stable sewers than house sewers, and therefore it may sometimes be advisable to be provided with some special design by which such foreign matters can be arrested. Moreover, it must not be forgotten that owing to the extra warmth of stables, sewer gases generated outside are more likely to enter them than the mansion itself. This is an extra reason for the adoption of the simple trap above mentioned.

Plan of Drains.

It is always advisable when a house has been provided with efficient water supply and sewerage, that there should be a correct plan of both works in the possession of the owner. This plan is most useful for future reference in case of accident. It should be drawn to an easily legible scale, framed and hung up in some suitable position.

Health Certificates.

No matter how well water supply and sewerage systems have been devised and executed, they always require periodical attention and inspection.

In my opinion both should be examined once every three, or six months at the most, by some competent person, who should test and examine all reservoirs, sewers and accessories. Machinery likewise should be tested in a similar manner by a competent engineer. It is also advantageous that once every year the person, or firm, who make the inspection, should issue a Certificate of Health. Owners, however, must remember that the value of this certificate should never extend beyond a twelvemonth, because all works of sewerage and water supply, like anything else, are liable to derangement. The certificate should be preserved, framed and hung up in proximity to the plan of the water and sewerage system previously referred to.

SEWAGE DISPOSAL.

It is now recognised by all sanitarians that cesspools are generally evils of the worst description; but when acknowledging this it cannot be denied that there are some country mansions in England where it is next door to impossible to avoid their adoption. Under such circumstances, if the sewage be taken to a considerable distance from the residence—a minimum 100 yards—and a cesspool then constructed in open brickwork, which shall allow of the liquid contents escaping into a porous soil, such as red sandstone, chalk, or one of the free oolitic beds, the sewage will probably soak away down to the subterranean water-level, wherever it may be, and never be seen or heard of again. If the depth be great, no mischief whatever may follow, but it is a system of disposal which I do not recommend, and which should always be avoided if possible. If, however, the water-level be near the surface, then the cesspool, if similarly constructed, with its unseen outpourings, though relieving the occupier of the residence of trouble or legal risks for a time, will remain liable to all the objections to which cesspools are admittedly subject; and it is

only by extreme care and an alteration in construction that nuisance can possibly be avoided.

The correct manner to construct a cesspool and arrange for its subsequent maintenance is as follows:—

It should be built of either concrete or brickwork in cement, backed behind with clay puddle and carefully rendered inside throughout so as to be water-tight. It should be provided with either one or two air-tight entrance openings, or doors, let into the roof, so that at any time it can be thoroughly ventilated and if necessary entered for inspection: and a 6-inch ventilating pipe should be conveyed from the roof, either by means of a stout tree, or a special support, up to such a height above ground level as to be out of harm's way. It should also be provided with an overflow pipe, the contents of which, when it comes into action, should pass through a small brick chamber, or filter, built in duplicate and containing stone and gravel before it either reaches a neighbouring ditch, or is discharged on to the surface and applied by means of irrigation to grass or arable land. At its point of connection with the cesspool this overflow pipe should be dipped or curved downwards, so as to enter it below the level of the impounded sewage. By this means the top scum is never carried down the pipe to choke the filter beyond, or clog the sides of the ditch or surface of the land below. The cesspool system (no matter what care is taken) is of course easily liable to abuse, and as I have

advised, it should, if possible, never be resorted to, because the provision of the necessary overflow in itself gives ready opportunities for the labourer whose duty it is to periodically empty the cesspool to avoid his obligations at the expense of his master's interests. It is almost needless to add that with a cesspool, a chain pump, or other simple description of pump, should be erected over it, so that the contents may be easily raised and removed by means of a water-tight sewage cart for application to adjacent garden or grass land. The overflow should then seldom, if ever, come into operation.

Land Treatment.

Far preferable to the adoption of cesspools is the purification of sewage either by natural filtration or irrigation over and through land or by artificial filtration in specially prepared beds subsequently aided by land treatment, because the use of land in some shape or other is essential to success.

There are few estates where a site of outfall and land in sufficient quantity cannot be obtained so as to ensure the accomplishment of the object aimed at by one means or the other.

With uniformly free soils no artificial treatment whatever is required; the liquid after screening and passage through ordinary storage tanks, so as to secure the deposition of mineral and other matters in suspension, being applied direct to the surface of land for purification. Where the soil

is not so uniformly free, or in other words where the proportion of a comparatively retentive soil is greater than that of the free soil, artificial filtration, though probably only to a limited extent, must be resorted to previous to land treatment; whilst with soils of an uniformly retentive character, artificial filtration, instead of being a minor feature, becomes the main form of treatment, the application of the effluent to the land after retention in the filters being looked upon as the completing process of purification instead of the principal one.

In no instance need the area for sewage disposal works in the case of a country mansion with its dependencies exceed a maximum two acres, to include fences, tanks, filter beds, roads, paths, etc., for in the case of the sewage disposal of towns it has for many years past been proved that with uniformly free soils (which I will term Class I.), one acre of land will efficiently purify the sewage discharged from at least 500 people; whilst with Class II., i.e. either a moderately free soil throughout, or a mixture of free and somewhat retentive soil, the same area will efficiently purify that discharged from 250 people; and with class III., that is to say, with an uniformly retentive soil, that discharged from about 100 people.

In all three classes—as with a town or village, so with a mansion—after the delivery of the sewage at the point of outfall, the first thing to do is to extract the larger coarse matters in suspension, which should be either immediately burnt or dug

into the ground, inasmuch as they prove no advantage whatever, but rather a detriment to any form of treatment. This extraction can be effected either by wrought-iron or cast-iron screens constructed of ¾-inch bars with ¾-inch spaces. These screens rest upon a perforated platform and are placed across the mouth of the outfall sewer, when by means of a rake made to fit the spaces, the solids can be readily raised to the surface. No nuisance results from this operation provided that it is systematically carried out. Indeed only an infinitely small area of land is required to satisfactorily dispose of the solid deposit in perpetuity.

With Class I. the tanks which I have mentioned need only be of the very simplest description. They should be built of either concrete or brickwork, and be constructed in duplicate, so as to ensure the necessary alternate period of use and rest for the purpose of cleaning. They may be covered and ventilated if desired, and their bottom or invert should be sloped towards a side sludge pit or sumpt, from which the mineral and smaller matters in suspension which have passed through the screens can be readily raised by a chain pump and dug into the adjacent soil. Each tank should contain at least twenty-four hours' flow of sewage, and should be provided with a penstock fixed across the bottom or lower wall, by the raising of which the contents can daily be discharged by the attendant on to the land below. Automatic methods of discharge are not, in my opinion, to be generally recommended.

With Class II. the tank may be of somewhat of the same description as in the last category, but in order to afford artificial help to the less free soil, the sewage should after screening pass through baskets or layers of filtering material (coarse gravel or broken ballast and fine gravel) before collection in the tanks. These baskets should be constructed so as to be easily removable for the purpose of cleaning, and their number should be determined according to the proportion which the free soil bears to the retentive soil.

With Class III. an entirely different system should be adopted, the simple storage and depositing tanks giving place to bacteria beds, by which means artificial filtration is substituted for natural. A successful result can then be obtained, even under most inauspicious circumstances, though of course at a greater outlay. It should be remembered that artificial filtration in reality in no way differs from natural filtration, because it simply produces by artificial means, i.e. by the burning of clay, etc., within a limited area (i.e. the four walls of the filter) the same results as nature produces by means of a free soil without such burning.

Bacteria beds are merely excavations out of the ordinary soil, their outside and divisional walls being of either concrete or brick work. If the levels render it necessary they can of course be built above ground, and the filtering material obtained from elsewhere. They should be filled with either burnt ballast or clinker, or coke breeze broken to a size

which will pass through a sieve with a 1½-inch mesh and be retained on a sieve with a ½-inch mesh.

Of course two, or even three, sets of filters, graduated in texture, can be provided if necessary. The water capacity of these filters, when filled with any of the above materials, represents about one-third of the total cubic capacity. They should contain in the aggregate two days' discharge, and be divided by cross walls into as many divisions as may be deemed necessary, so that each in turn may be filled with sewage and then emptied, thus ensuring that period of rest which is as necessary for artificial filtration as for natural.

The process of purification within an artificial filter is as follows. The material placed in the beds provides the germs or organisms, which are always present in crude sewage, with the means of carrying out their life work, which is the liquefaction of the organic solids. These organisms in the first place require warmth. This is obtained for them in the body of the bed. They next require air or oxygen, which is conveyed to them by the periodical emptying of the beds and the subsequent rest before being again brought into use; and lastly they must have nutriment, and this is brought to them by the re-admission of crude sewage. When a bed is filled, the organisms are digesting or peptonising the organic constituents of the sewage, extracting the nitrogenous particles, and converting them into ammonia and water, and finally into nitrates and nitrites. When a bed is empty, the organisms breed very

rapidly, and in this manner the body of the filtering material is prepared for the next dose of sewage.

It will thus be seen that by working bacteria beds in a regular cycle of alternate periods of (1) filling, (2) remaining full and of quiescence, (3) emptying and remaining empty, and (4) of refilling, they could be maintained in a thorough state of efficiency for all time if crude sewage was comprised of organic matters only. There are, however, always certain inorganic or insoluble matters in sewage, which with treatment under Classes I. or II. would be allowed to settle, and be collected in the sludge pits of the tanks previously described; but as in this class pits underneath the bacteria beds would be impracticable, a small detritus chamber should be provided between the screens and the filters, so as to prevent the admission of mineral matters. If some such arrangement as this is not carried out, their efficiency will in course of time become impaired, and then the occasional removal and cleansing of the filtering material will become necessary. With properly constructed beds, however, on the lines indicated, several years will elapse before any removal or cleansing is required.

The method of discharge from the bacteria beds on to the land for the final purification of the effluent is the same as in the previous instances.

All land prepared for the purification of sewage must be laid out in one of two ways, either (1) by intermittent filtration, (2) by wide irrigation.

Purification by intermittent filtration, a treatment which may most profitably be resorted to with flat and porous soils, is carried out on perfectly flat terraces, or areas of land formed into ridges (somewhat similar in form to asparagus beds) 6 to 8 feet wide, and intersected by furrows about 15 inches wide at the top, 12 inches deep and 9 inches wide at the bottom. Down these furrows the sewage flows when released from the tanks or bacteria beds, and it may be allowed to rise until it reaches a few inches off the surface of the ridges. When an area is thus filled the sewage is turned on to another, three or four always being provided so as to secure the periodical aeration of the soil. It will thus be seen that purification on these natural areas is effected in precisely the same manner as with artificial filter beds, because not only are the same organisms at work in both instances, but the rotatory rules as regard filling, emptying and rest must be equally observed.

Intermittent natural filtration is the best recognised method of purifying large quantities of sewage on limited areas of free soil. It was first adopted at Merthyr Tydvil in 1870, by my late father in conjunction with the late Sir Edward Frankland, K.C.B., F.R.S., and it has been largely carried out ever since in this country, not only in the case of cities and towns, but also of country mansions. Indeed some of the most successful works for which I have recently been responsible are the "Filtration" sewaged gardens of isolated dwellings.

No better evidence in support of this opinion and experience can be adduced than the quotation of an extract from the last "Royal Commission on Metropolitan Sewage Discharge (Lord Bramwell's Commission, 1884)." The Commissioners say with regard to intermittent filtration, "The best means of applying sewage to land is by means of Intermittent Filtration" They moreover summarise matters by stating that, notwithstanding the fact that during the last thirty years chemical treatment has received the concentrated attention of the most eminent chemists, it is still recognised that in order to produce a sewage effluent of any substantial degree of purity, land must be resorted to in some form or other.

Wide irrigation is the oldest and perhaps the simplest form of sewage treatment, and is still frequently adopted on sloping surfaces, in order to save the great expense of making flat terraces on land with this configuration. Under such circumstances care must be taken to minimise the slope, if it is steep, and to secure a gradual and uniform fall from top to bottom. The sewage is conveyed in equal quantities over the whole surface by means of small furrows following the natural contours of the land. In the same way as with filtration, the liquid must never be applied continuously over one or the same portion, but in rotation over the whole, otherwise a successful effluent is not obtained. At the bottom of the slope a strip of flat land is always advisable and generally obtain-

able. This strip should be deeply trenched. The liquid is by this means able to percolate through the soil, and thus does not flow off the surface directly into the outfall ditch. It will be seen that with wide irrigation in contradistinction to intermittent filtration, small quantities of sewage are utilised over comparatively large areas of ground instead of large quantities over small.

UNDER-DRAINAGE.

Both filtration areas and irrigation land should be carefully under-drained to a minimum depth of 5 feet, so as to aid the porosity of the soil and ensure that no liquid shall remain for any length of time to stagnate upon the surface. In most cases under-drains consist of common agricultural unjointed butt pipes, either 6 inches or 4 inches in diameter. With filtration areas these under-drains should be laid under the centre of the ridges, and not beneath the furrows, so that the liquid may be conveyed down to them laterally and not vertically. Their distance apart varies according to the porosity or tenacity of the soil.

On irrigation land under-drains are laid in herring-bone fashion without any definite rule as to position. With very retentive clays, the trenches above the pipes should be filled with burnt ballast carefully rammed, so that the liquid can, after passage over the land, the more readily descend down to them.

Branch under-drains are generally connected with a main of larger diameter laid approximately parallel to the base of the sewaged land, which main is connected with the nearest brook. The outlet is generally of brickwork, protected at the mouth by either tide-flap or grating, so that neither uprising flood water or vermin can enter the under-drains. Inspection chambers or manholes should always be built at suitable points along the course of the pipes, so that the character of effluent can at any time be ascertained and defects localised. These shafts should be provided with ventilating covers, in order that a free current of air should permeate the system.

CROPS.

Upon the ridges of filtration areas, the under-mentioned crops may be successfully grown :— Savoys of all sorts, cabbages, black and red currants, and strawberries, whilst rose-trees thrive on sewaged gardens in a remarkable manner. Care must, however, be always taken that the row of plants or vegetables nearest to the furrows are sufficiently far away from them to ensure that their leaves should never come into actual contact with the sewage.

Upon wide irrigation land, cow cabbage, mangolds, turnips, and rye grass may be grown to advantage, but crops of cereals should never be

attempted. Sewage should never be applied to crops for a fortnight previous to sale or use.

It is now recognised that, under all circumstances, the value of the crops grown should far more than counter-balance the wages of the necessary attendant and the cost of seeds.

COST OF WORKS, METHOD OF OBTAINING LOAN, TERMS FOR REPAYMENT, ETC.

I will now briefly discuss the question of outlay, and explain how the somewhat heavy expense which is, and must always be, inevitably connected with works of improvement, may be best met. Of course the expenditure involved may vary from a few hundreds to several thousands of pounds; and in the latter case a landowner may be put to considerable inconvenience if he has himself to find the requisite money in a lump sum down. The legislature have, however, stepped in beneficially, and in consequence there are several Acts of Parliament by which he is enabled to effect a loan on advantageous terms, not only for works of water supply in relation to his mansion and estate, but for the sewerage works connected with his residence. All these Acts are administered by the Board of Agriculture, whose offices are in St. James's Square, London.

With regard to the sewerage and sewage disposal of a residence, the Limited Owners' Residences Acts (1875) enable an owner, whether tenant for

life, or owner in fee, to borrow money, and to charge the estate with the outlay necessary to complete all these works, provided that the total sum expended, together with all expenses incidental to obtaining the loan as well as professional charges, does not exceed two years' net rental from the estate mortgaged ; that is to say, his clear income after the payment of all charges previously created.

With regard to water supply, by the adoption of the Improvement of Land Acts, an owner may not only charge his property with the cost of all outlay, but, under the same charge, he may supply his neighbours—in other words, if a squire owns two-thirds of the houses in a village, he can supply the remaining one-third with water, upon agreed terms, and thus not only benefit the district in which he lives, but at the same time, by means of the consequent rental, reduce the annual amount which he has to pay to the insurance or other company with whom he has effected the loan. My firm recently carried out at a village in Somersetshire, on behalf of a peer lately deceased, a water supply exactly on these lines. In this instance, in addition to the mansion, farm, homesteads, etc., on the estate, all the houses in the village, including the rectory, which did not belong to him, are supplied with water from his property at fixed rentals, such as are not beyond the power of payment by tenants of limited means.

Naturally the amount of rental depends upon the value placed upon water in the district to be

supplied, because if water is locally scarce its value is obviously higher than if it is plentiful.

The repayment of loans for improvements (principal with interest) is spread over a period of years varying from twenty to forty years, and is repaid by equal half-yearly instalments.

There are two companies in England which possess private Acts of Parliament, and which lend money in this way, subject, of course, to the control of the Board of Agriculture, whose inspectors in each case visit the locality, both before the works are commenced and at their conclusion, and upon whose reports the loans are sanctioned—one is the General Land Drainage and Improvement Company, with offices at Palace Chambers, Westminster, which company was incorporated as far back as 1849, and the other is the Lands Improvement Company, with offices in Great George Street, Westminster. The first, which is the elder of these two companies, at the present time advances money at 3½ per cent. interest, which with the necessary provision for the gradual liquidation of the principal, makes the total annual rate to be as follows :—

20 years' loan	£6	19	10¾	per cent.
25 ,,	6	0	8¼	,,
30 ,,	5	8	2½	,,
35 ,,	4	19	6¾	,,
40 ,,	4	13	3½	,,

As I have previously said, all preliminary ex-

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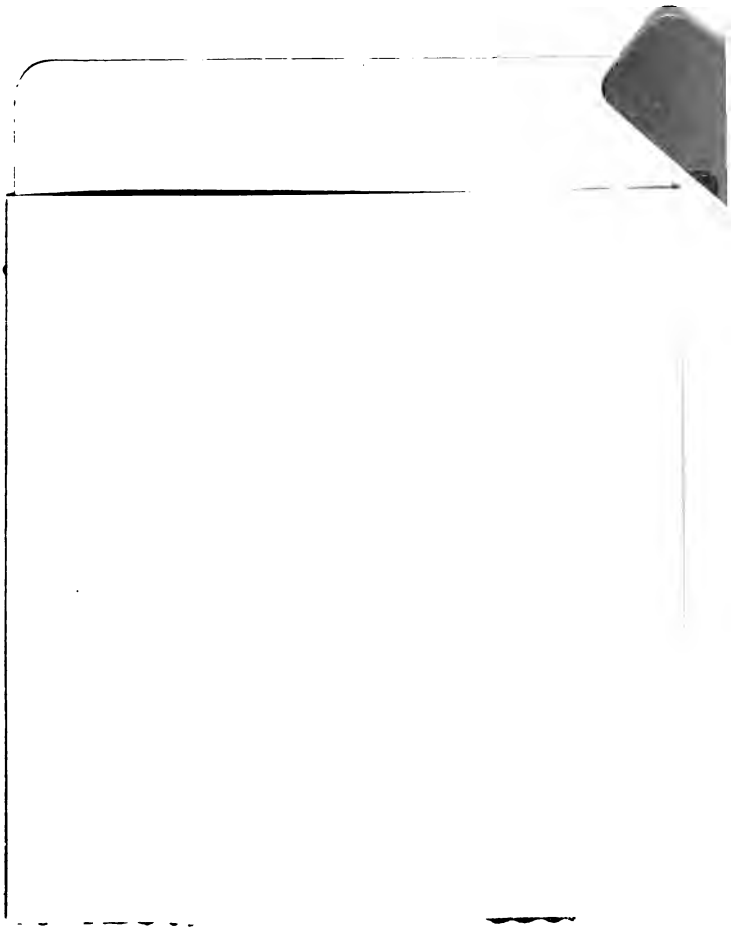
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